

LINED WATERWAY OR OUTLET

(Feet)
Code 468

Natural Resources Conservation Service
Conservation Practice Standard

I. Definition

A waterway or outlet having an erosion-resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes to a designed depth. The earth above the permanent lining may be vegetated or otherwise protected.

II. Purposes

To provide for safe disposal of runoff from other conservation structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate. Properly designed linings may also control seepage, piping, and sloughing or slides.

III. Conditions Where Practice Applies

This practice applies to waterways or outlets having linings of reinforced or non-reinforced, cast in-place concrete; flagstone mortared in place; rock riprap; or similar permanent linings if the following or similar conditions exist:

- Concentrated runoff is such that a lining is needed to control erosion.
- Steep grades, wetness, prolonged base flow, seepage, or piping would cause erosion.
- The location is such that use by people or animals preclude use of vegetated waterways or outlets.
- High-value property or adjacent facilities warrant the extra cost to contain design runoff in a limited space.
- Soils are highly erosive or other soil or climatic conditions preclude using vegetation.

This practice does not apply to:

- Irrigation water conveyance, grassed waterways with stone centers or small lined sections to carry prolonged low flows.
- Waterways that exceed a capacity of 200 cubic feet per second when flowing at design depth.
- Rock chute grade stabilization structures.

IV. Federal, State, and Local Laws

Users of this standard should be aware of potentially applicable federal, state and local laws, rules, regulations or permit requirements governing lined waterways or outlets. This standard does not contain the text of federal, state, or local laws.

V. Criteria

The following criteria apply to all purposes.

A. Capacity

The minimum capacity shall be adequate to convey the peak discharge from a 10-year frequency 24-hour duration storm. Velocity shall be computed by using Manning's Formula with a coefficient of roughness "n" as follows:

Table 1
Manning's "n" Values

Lining	"n" Value
Concrete	
Trowel finish	.012 - .014
Float finish	.013 - .017
Guniting	.016 - .022
Flagstone	.020 - .025
Rock Riprap	Determine from Table 2

Table 2
Manning's "n" Values for Various
Sizes of Rock Riprap

D ₅₀ *		n= 0.04D ^{1/6**}
(inches)	(feet)	
2	0.17	.030
4	0.33	.033
6	0.50	.036
8	0.67	.037
10	0.83	.039
12	1.00	.040

* Where 'D' is diameter of rock, the size of which is such that by weight, 50% is larger and 50% is smaller than this diameter.

**D in feet.

B. Velocity

The maximum design velocity for linings other than rock shall be as shown in Figure 1.

The maximum design velocity for rock lining shall be the product of the velocity shown in Table 3 times the appropriate slope adjustment factor from Table 4.

Except for short transition sections, flow in the range of 0.7 to 1.3 of the critical slope must be avoided unless the channel is straight. Velocities exceeding the critical velocity shall be restricted to straight reaches.

Waterways or outlets with velocities exceeding the critical velocity shall discharge into an energy dissipater to reduce the outflow velocity to less than critical.

Table 3
Maximum Velocities for Various
Rock Sizes and Shapes

D₅₀ Cubical (inches)	D₅₀ Spherical (inches)	Maximum Velocity (fps)
12	--	10.8
10	12	9.9
8	10	8.8
6	8	7.6
4	6	6.3
3	4	5.3
2	3	4.3

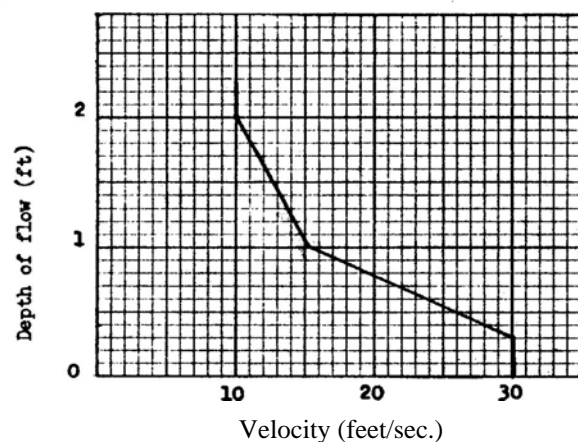
Table 4
Slope Adjustment Factors to
Maximum Velocity for Rock Lining

Slope (horizontal to vertical)	Slope (ft/ft)	Adjustment* Factor
3:1	0.33	0.80
4:1	0.25	0.85
5:1	0.20	0.89
6:1	0.17	0.91
7:1	0.14	0.92
8:1	0.13	0.93
9:1	0.11	0.94
≥10:1	0.10	1.00

* Factor = $\sqrt{\cos \theta - \sin \theta}$
 θ = angle of bed slope

Figure 1

Maximum Velocity vs. Depth of
Flow for Linings Other Than Rock



C. Cross Section

The cross section shall be triangular, parabolic, or trapezoidal. Cross sections made of monolithic concrete may be rectangular. Riprap shall be placed so that it does not reduce the design cross section.

The steepest permissible side slopes, horizontal to vertical (h:v), shall be:

Table 5
Steepest Permissible Side Slopes

Lining Material	Side Slope (h:v)
Hand-placed, formed concrete* Height of lining, 1.5 feet or less	Vertical
Hand-placed screeded concrete* or mortared-in-place flagstone Height of lining, less than 2 feet	1:1
Height of lining, more than 2 feet	2:1
Slip form concrete: Height of lining, less than 3 feet	1:1
Rock riprap	2:1

*Non-reinforced concrete

D. Freeboard

The minimum freeboard for all rock-lined waterways or outlets shall be 0.25 feet above the design water depth. If erosion-resistant vegetation cannot be grown adjacent to the rock-lined side slopes, an additional 0.25 feet of freeboard will be added (0.5 feet total).

The minimum freeboard for all other lined waterway materials shall be 0.25 feet above the design water depth where erosion-resistant vegetation cannot be grown adjacent to the lined side slope.

No freeboard is required for linings (other than riprap) if vegetation can be grown and maintained.

E. Lining Thickness

Minimum lining thickness shall be:

Table 6
Lining Thickness

Lining Material	Thickness
Concrete	4 inches (without reinforcement) 5 inches (steel bar reinforcement)
Rock riprap	Maximum stone size plus thickness of filter or bedding
Flagstone	4 inches, including mortar bed

F. Concrete

Concrete mixes used for lining shall be proportioned so that it is plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense durable product shall be required. Concrete shall meet or exceed the requirements of Wisconsin Construction Specification 4, Concrete.

Contraction joints, if required, shall be formed transversely to a depth of about one-third the thickness of the lining at a uniform spacing in the range of 10 to 15 feet. Contraction joint spacing may be increased based on design procedures used in industry guidelines such as the American Concrete Institute. Uniform support to the joint to prevent unequal settlement shall be provided.

G. Rock Riprap or Flagstone

Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing, and thawing. Rock shall meet the material requirements of Wisconsin Construction Specification 9, Loose Rock Riprap.

The rock gradation shall be:

Table 7
Rock Riprap Gradation

Percent passing by weight	Size (inches)*
100	2 x D ₅₀
60-85	1.5 x D ₅₀
25-50	D ₅₀
5-20	0.5 x D ₅₀
0-5	0.2 x D ₅₀

*round to nearest inch

Flagstone shall be flat for ease of placement and have the strength to resist exposure and breaking. Mortar used for mortared in-place flagstone shall consist of a workable mix of cement, sand, and water with a water-cement ratio of not more than 6 gallons of water per bag of cement (94 pounds).

H. Filters or Bedding

Filters, bedding, or geotextiles shall be used to prevent piping of base materials through the lining. Drainage shall be used to reduce uplift pressure and to collect water, as required. Weep holes may be used with drains if needed.

I. Related Structures

Side inlets, drop structures, and energy dissipaters shall meet the hydraulic and structural requirements for the site.

J. Crossings

Crossings shall be in accordance with the criteria contained in NRCS FOTG Standard 578, Stream Crossing.

VI. Considerations

Additional recommendations relating to design which may enhance the use of, or avoid problems with, this practice, but are not required to ensure its basic conservation function are as follows:

- A. Effects on components of the water budget, especially effects on volumes and rates of runoff, infiltration, evaporation, transpiration, deep percolation, and groundwater recharge.
- B. Variability of the practice's effect caused by seasonal and climatic changes.
- C. Filtering effects of adjacent vegetation on the movement of sediment and dissolved and sediment attached substances.
- D. Effects on the visual quality of landscape or water resources.
- E. Short-term and construction-related effects on the quality of water resources.

VII. Plans and Specifications

Plans and specifications for constructing lined waterways or outlets shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purposes.

VIII. Operation and Maintenance

An Operation and Maintenance Plan shall be developed that is consistent with the purpose of this practice, intended life of the components, and criteria for design.

The plan shall include but is not limited to:

- A. Inspection of channel linings and outlets periodically and after major runoff events.
- B. Replacement of lining materials damaged by runoff events.
- C. Vegetation shall be maintained and trees and brush controlled by hand, chemical, or mechanical means.

IX. References

USDA, NRCS, Wisconsin Field Office Technical Guide, Section IV, Conservation Practice Standards and Specifications.